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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Anticipated Classification

Class _____ Subclass _____

PATENT APPLICATION
Honorable Commissioner of Patents
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Washington, DC 20231

Sir:

Transmitted herewith for filing is the patent application of Kei-Yu Ko, for UNDOPED SILICON DIOXIDE AS ETCH STOP FOR SELECTIVE ETCH OF DOPED SILICON DIOXIDE comprising 32 pages of specification and claims, and a Declaration, Power of Attorney and Petition.

Enclosed also are:

- 2 sheets of drawings
- An assignment of the invention to Micron Technology, Inc., including a Form PTO-1595 recordation cover sheet.
- A certified copy of an _____ application.
- An Associate Power of Attorney
- A Verified Statement to Establish Small Entity Status Under 37 C.F.R. § 1.9 and 37 C.F.R. § 1.27

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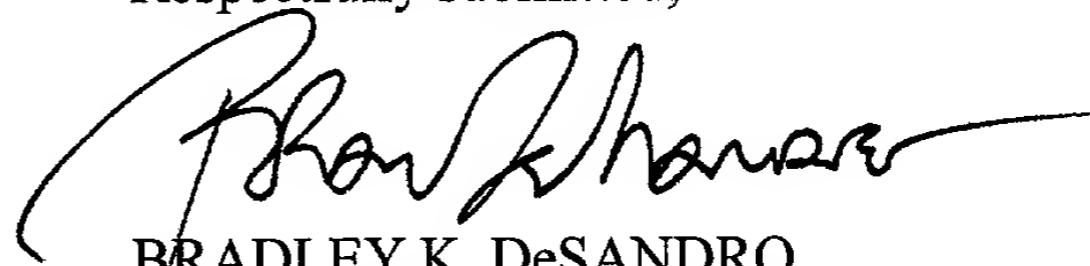
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x Any filing fees under 37 C.F.R. § 1.16 for presentation of extra claims.

Please address all future correspondence in connection with the above-identified patent application to the attention of the undersigned.

Dated this 30th day of April, 1997.

Respectfully submitted,



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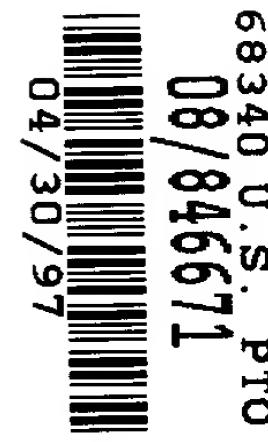
UNITED STATES PATENT APPLICATION

OF

KEI-YU KO

FOR

UNDOPED SILICON DIOXIDE AS ETCH STOP
FOR SELECTIVE ETCH OF DOPED SILICON DIOXIDE



BACKGROUND OF THE INVENTION

1. The Field of the Invention

The present invention involves an etching process that utilizes an undoped silicon dioxide layer as an etch stop during a selective etch of a doped silicon dioxide layer that is situated on a semiconductor substrate. More particularly, the present invention relates to a process for selectively utilizing a fluorinated chemistry in a plasma etch system for etching a doped silicon dioxide layer situated upon an undoped silicon dioxide layer that acts as an etch stop.

2. The Relevant Technology

Modern integrated circuits are manufactured by an elaborate process in which a large number of electronic semiconductor devices are integrally formed on a semiconductor substrate. In the context of this document, the term "semiconductive substrate" is defined to mean any construction comprising semiconductive material, including but not limited to bulk semiconductive material such as a semiconductive wafer, either alone or in assemblies comprising other materials thereon, and semiconductive material layers, either alone or in assemblies comprising other materials. The term substrate refers to any supporting structure including but not limited to the semiconductive substrates described above.

Conventional semiconductor devices which are formed on a semiconductor substrate include capacitors, resistors, transistors, diodes, and the like. In advance manufacturing of integrated circuits, hundreds of thousands of these semiconductor devices are formed on a single semiconductor substrate. In order to compactly form the semiconductor devices, the semiconductor devices are formed on varying levels of the semiconductor substrate. This requires forming a semiconductor substrate with a topographical design.

The semiconductor industry is attempting to increase the speed at which integrated circuits operate, to increase the density of devices on the integrated circuits, and to reduce

1 the price of the integrated circuits. To accomplish this task, the semiconductor devices used
2 to form the integrated circuits are continually being increased in number and decreased in
3 dimension in a process known as miniaturization.

4 One component of the integrated circuit that is becoming highly miniaturized is the
5 active region. An active region is a doped area in a semiconductor substrate that is used
6 together with other active regions to form a diode or a transistor. The miniaturization of the
7 active region complicates the formation of the interconnect structure in that, in order to
8 maintain sufficient electrical communication, the interconnect structure must be formed in
9 exact alignment with the active region. Also, the area of the interconnect structure
10 interfacing with the active region must be maximized. Thus, less area is provided as
11 tolerance for misalignment of the interconnect structure.

12 The increasing demands placed upon manufacturing requirements for the interconnect
13 structure have not been adequately met by the existing conventional technology. For
14 example, it is difficult at greater miniaturization levels to exactly align the contact hole with
15 the active region when patterning and etching the contact hole. As a result, topographical
16 structures near the bottom of the contact hole upon the active region can be penetrated and
17 damaged during etching of the contact hole. The damage reduces the performance of the
18 active region and alters the geometry thereof, causing a loss of function of the semiconductor
19 device being formed and possibly a defect condition in the entire integrated circuit. To
20 remedy these problems, the prior art uses an etch stop to prevent over etching.

21 In a conventional self-aligned etch process for a contact hole, a silicon nitride layer
22 or cap is usually used on top of a gate stack as an etch stop layer during the self-aligned
23 contact etch process. One of the problems in the prior art with forming a silicon nitride cap
24 was the simultaneous formation of a silicon nitride layer on the back side of the
25 semiconductor wafer. The particular problems depend on the process flow. For instance,
26 where a low pressure chemical vapor deposition is used to deposit silicon nitride, both sides

1 of the semiconductor wafer would receive deposits of silicon nitride. The presence of the
2 silicon nitride on the back side of the semiconductor wafer causes stress which deforms the
3 shape of the semiconductor wafer, and can also potentially cause deformation of the crystal
4 structure as well as cause defects in the circuit. Additionally, silicon nitride deposition is
5 inherently a dirty operation having particulate matter in abundance which tends to reduce
6 yield. When a low pressure chemical vapor deposition process is utilized, the silicon nitride
7 layering on the back side of the semiconductor wafer must be removed later in the process
8 flow.

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SUMMARY OF THE INVENTION

The present invention relates to a process for selectively plasma etching a semiconductor substrate to form a designated topographical structure thereon utilizing an undoped silicon dioxide layer as an etch stop. In one embodiment, a substantially undoped silicon dioxide layer is formed upon a layer of semiconductor material. A doped silicon dioxide layer is then formed upon the undoped silicon dioxide layer. The doped silicon dioxide layer is etched to create a topographical structure. The etch has a material removal rate that is at least 10 times higher for doped silicon dioxide than for the undoped silicon dioxide or the layer of semiconductor material.

One application of the inventive process includes a multilayer structure situated on a semiconductor substrate that comprises layers of a semiconductor material, a thin silicon dioxide layer, a layer of conductor material, and a refractory metal silicide layer. By way of example, the multilayer structure situated on a semiconductor substrate may consist of a gate oxide situated on a silicon substrate, a layer of polysilicon, and a refractory metal silicide layer on the layer of polysilicon. A substantially undoped silicon dioxide layer is then formed over the multilayer structure.

The multilayer structure is then patterned to form the designated topography. Doped silicon dioxide is then formed on the semiconductor substrate as a passivation layer. A photoresist layer is utilized to expose selected portions of the doped silicon dioxide layer that are intended to be etched. One example of a topographical structure created utilizing this process are gate stacks. The doped silicon dioxide is then selectively and anisotropically etched with a carbon fluorine etch recipe so as to self-align contact holes down to the semiconductor substrate between the gate stacks.

Each gate stack has a cap composed of substantially undoped silicon dioxide. A layer of silicon nitride or undoped silicon dioxide is deposited over the gate stacks and the semiconductor substrate therebetween. A spacer etch is performed to create silicon nitride

1 or undoped silicon dioxide spacers on the side of each gate stack. The silicon nitride or
2 undoped silicon dioxide spacers are generally perpendicular to the base silicon layer.

3 The present invention contemplates a plasma etching process for anisotropic etching
4 a doped silicon dioxide layer situated on an undoped dioxide layer that acts as an etch stop.
5 One application of the present invention is the formation of gate stacks having spacers
6 composed of substantially undoped silicon dioxide. The undoped silicon dioxide spacers act
7 as an etch stop. Novel gate structures are also contemplated that use a substantially undoped
8 silicon dioxide etch stop layer for a carbon fluorine etch of a doped silicon dioxide layer,
9 where the substantially undoped silicon dioxide etch stop layer resists etching by a carbon
10 fluorine etch.

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BRIEF DESCRIPTION OF THE DRAWINGS

In order that the manner in which the above-recited and other advantages and objects of the invention are obtained, a more particular description of the invention briefly described above will be rendered by reference to specific embodiments thereof which are illustrated in the appended drawings. Understanding that these drawings depict only typical embodiments of the invention and are therefore not to be considered limiting of its scope, the invention will be described with additional specificity and detail through the use of the accompanying drawings in which:

Figure 1 is a partial cross-sectional elevation view of one embodiment of a multilayer structure prior to an etch, the multi-layer structure including a base silicon layer and a layer of undoped silicon dioxide, where the multi-layer structure has a layer of photoresist, and wherein a first selected pattern is defined in phantom.

Figure 2 is a partial cross-sectional elevation view of the structure seen in Figure 1, wherein the layer of undoped silicon dioxide has been etched so as to form a recess terminating upon the base silicon layer, a layer of doped silicon dioxide has been deposited thereover, where a layer of photoresist is formed over the layer of doped silicon dioxide, and wherein a second selected pattern is defined in phantom which is intended to represent an etch through the layer of doped silicon dioxide to expose a contact on the base silicon layer that is self-aligned between the layer of undoped silicon dioxide, wherein the self-alignment of the etch is due to the selectivity of the etch to undoped silicon dioxide.

Figure 3 is a partial cross-sectional elevation view of one embodiment of a multilayer structure prior to an etch, the multilayer structure including a base silicon layer and having thereon layers of gate oxide, polysilicon, tungsten silicide, and undoped silicon dioxide, where the multi-layer structure has a layer of photoresist, and wherein a first selected pattern is defined in phantom.

1 Figure 4 is a partial cross-sectional elevation view of the structure seen in Figure 3,
2 wherein gate stacks are formed upon the base silicon layer, each gate stack having a spacer
3 on a sidewall thereof and a cap on the top thereof, the gate stacks having deposited thereover
4 a layer of doped silicon dioxide, and a layer of photoresist is deposited upon the layer of
5 doped silicon dioxide, wherein a second selected pattern is defined in phantom which is
6 intended to represent a fluorinated chemical etch through the layer of doped silicon dioxide
7 to expose a contact on the base silicon layer that is self-aligned between the gate stacks,
8 wherein the self-alignment of the etch is due to the selectivity of the etch to the materials of
9 the spacers and the cap of the gate stacks.

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1 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

2 The inventive process herein is directed towards selectively utilizing a plasma etch
3 system on doped silicon dioxide (SiO_2) layer with a substantially undoped silicon dioxide
4 layer as an etch stop. One application of the inventive process is to form a self-aligned
5 contact. The present invention also discloses an inventive multilayer gate structure.

6 As illustrated in Figure 1, one embodiment of a multilayer structure 10 is created
7 that comprises a base silicon layer 12. Overlying silicon base layer 12 is a substantially
8 undoped silicon dioxide layer 22. Undoped silicon dioxide layer 22 can be any type of
9 undoped oxide and be formed by a thermal process, by a plasma enhanced deposition
10 process, or by a conventional TEOS precursor deposition that is preferably rich in carbon or
11 hydrogen, or by a precursor of gaseous silane (SiH_4) with oxygen. In the latter process, the
12 gaseous silane flow will result in undoped silicon dioxide layer 22.

13 The next layer in the embodiment of multilayer structure 10 illustrated in Figure 1
14 comprises a photoresist layer 24 that is processed to expose a first selected pattern 15, shown
15 in phantom, such that silicon dioxide layer 22 will be used to create a topography in
16 multilayer structure 10. Multilayer structure 10 is then anisotropically etched as shown by
17 first selected pattern 15 to selectively remove material from undoped silicon dioxide layer 22
18 to form undoped silicon dioxide caps 16 as seen in Figure 2.

19 A doped silicon dioxide layer 30 is deposited over multilayer structure 10 as a
20 passivation layer. Preferably, doped silicon dioxide layer 30 is substantially composed of
21 borophosphosilicate glass (BPSG), borosilicate glass (BSG), or phosphosilicate glass (PSG).
22 Most preferably, doped silicon dioxide layer 30 is substantially composed of silicon dioxide
23 having doping of about 3% or more for boron and about 3% or more for phosphorus. A
24 photoresist layer 32 is applied over doped silicon dioxide layer 30. Photoresist layer 32 is
25 processed to expose a second selected portion 17 of doped silicon dioxide layer 30 that is
26 intended to be etched. Second selected portion 17 is seen in phantom in Figure 2.

1 The structure seen in Figure 2 is now etched with a fluorinated or fluoro-carbon
2 chemical etchant system to form second selected pattern 17 as illustrated in Figure 2. The
3 preferred manner is an anisotropic plasma etch of doped silicon dioxide layer 30 down to the
4 corresponding etch stop layer of undoped silicon dioxide cap 16. The plasma etch technique
5 employed herein is preferably generated under a vacuum within the confines of a discharging
6 unit and involves any type of a plasma system, including a high density plasma etcher. A
7 conventional radio frequency reactive ion etcher (RF RIE) plasma system, a magnetically
8 enhanced RIE (MERIE) plasma system, or an inductively coupled plasma system could be
9 used. The preferred embodiment, however, is an RF type RIE or MERIE plasma system.
10 It is preferred the plasma system being used has a plasma density in a range from about
11 $10^9 / \text{cm}^3$ to about $10^{11} / \text{cm}^3$. A high density plasma system can also be used having a plasma
12 density in a range from about $10^{12} / \text{cm}^3$ to about $10^{13} / \text{cm}^3$.

13 One particular embodiment of a specific structure created utilizing the inventive
14 process is illustrated in Figure 3 wherein a multilayer structure 50 is created that comprises
15 a base silicon layer 12. Overlying silicon base layer 12 is a gate oxide layer 14 that covers
16 silicon base layer 12. Gate oxide layer 14 may be relatively thin in comparison with the
17 other layers of the multilayered structure. The next layer in multilayer structure 50
18 comprises a polysilicon gate layer 18. Overlying polysilicon gate layer 18 is a refractory
19 metal silicide layer 20. A known benefit of refractory metal silicides is their low resistivity.
20 Refractory metal silicide layer 20 may comprise any refractory metal including but not
21 limited to titanium, tungsten, tantalum, and molybdenum. Preferably, refractory metal
22 silicide layer 20 is substantially composed of tungsten silicide (WSi_x).

23 Overlying refractory metal silicide layer 20 is a substantially undoped silicon dioxide
24 layer 22 which can be formed thermally, by plasma enhanced deposition, by a conventional
25 TEOS precursor deposition that is preferably rich in carbon or hydrogen, or by a precursor
26 of gaseous silane (SiH_4) with oxygen. The next layer in multilayer structure 50 is a

1 photoresist layer 24 that is processed to expose a first selected pattern 15 shown in phantom.
2 Multilayer structure 50 is then etched according to first selected pattern 15 to selectively
3 remove material so as to form gate stacks 26 as illustrated in Figure 4. Each gate stack 26
4 has an undoped silicon dioxide cap 52 thereon which was formed from undoped silicon
5 dioxide layer 22.

6 A spacer 28 is on the sidewall of each gate stack 26. Spacers 28 are formed by
7 subjecting a layer of silicon nitride deposited over gate stacks 26 to a spacer etch. Silicon
8 nitride spacers 28 are generally perpendicular to silicon base layer 12. Alternatively,
9 spacers 28 can be substantially composed of undoped silicon dioxide. As such, both
10 spacers 28 and undoped silicon dioxide caps 52 can be made from the same materials and
11 both act as an etch stop.

12 Once gate stacks 26 are formed, a contact 34 is defined therebetween upon silicon
13 base layer 12. At this point in the processing, a doped silicon dioxide layer 30, composed of
14 a material such as PSG, BSG, or BPSG, is deposited over multilayer structure 50. A
15 photoresist layer 32 is then applied over doped silicon dioxide layer 30. Photoresist layer 32
16 is processed to create a second selected pattern 17 that is illustrated in phantom in Figure 4.

17 The structure seen in Figure 4 is now etched with a fluorinated or fluoro-carbon
18 chemical etchant system according to second selected pattern 17. The preferred manner of
19 etching of doped silicon dioxide layer 30 down to its corresponding etch stop layer, which
20 is substantially undoped silicon dioxide layer 52, is by a plasma etch. The etch technique
21 employed herein is preferably a plasma etch involving any type of a plasma system including
22 a high density plasma etcher as previously discussed relative to Figure 2.

23 One factor that effects the etch rate and the etch selectivity of the process is pressure.
24 The total pressure has a preferred range from about 1 millitorr to about 400 millitorr. A more
25 preferred pressure range for a plasma etch is in a pressure range from about 1 millitorr to
26 about 100 millitorr. The most preferred pressure range for a plasma etch is from about

1 1 millitorr to about 75 millitorr. The pressure may be increased, however, above the most
2 preferred ranges. For example, the RIE etch may be performed at about 100 millitorr.
3 Selectivity can be optimized at a pressure range between about 10 millitorr and about
4 75 millitorr. Pressure increases may result in a loss in selectivity. The range in selectivity,
5 however, can be adjusted to accommodate different pressures. As such, selectivity and
6 pressure are inversely related.

7 Temperature is another factor that effects the selectivity of the etching process used.
8 A preferable temperature range during the plasma etch has a range of about 10°C to about
9 80°C, and more preferably about 20°C to about 40°C. This is the temperature of a bottom
10 electrode adjacent to silicon layer 12 during the etching process. The preferable range of the
11 semiconductor materials is between about 40°C and about 130°C, and more preferably
12 between about 40°C and about 90°C.

13 Undoped silicon dioxide cap 52 and silicon nitride spacers 28 protect gate stacks 26
14 from the fluorinated chemical etch. As illustrated in Figure 4, the etch will selectively and
15 anisotropically remove doped silicon dioxide layer 30 above contact 34 as indicated by
16 second selected pattern 17. The etch removes material from doped silicon dioxide layer 30
17 at a higher material removal rate than that of undoped silicon dioxide cap 52 and silicon
18 nitride spacers or undoped silicon dioxide spacers 28. Preferably, the etch has a material
19 removal rate for doped silicon dioxide is at least 10 times higher than that of undoped silicon
20 dioxide. As such contact 34 is self-aligned between spacers 28 of gate stacks 26. The
21 self-aligning aspect of contact 34 is due to the selectivity of the etch which assures that even
22 in cases of misalignment of the exposure of second selected pattern 17, the fluorinated
23 chemical etch through doped silicon dioxide layer 30 will properly place contact 34 on
24 silicon base layer 12 and between adjacent silicon nitride spacers 28 that have been formed
25 upon sides of gate stacks 26.

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1 Contact 34 is preferably exposed by an anisotropic plasma etch with a fluorinated
2 chemistry that etches through BSG, PSG, BPSG, or doped silicon dioxide in general. The
3 etch is preferably selective to undoped silicon dioxide, silicon, and silicon nitride. The
4 fluorinated chemical etch utilizes a type of carbon fluorine gas from the group consisting of
5 C₂F₆, CF₄, C₃F₈, C₄F₁₀, C₂F₈, CH₂F₂, CHF₃, C₂HF₅, CH₃F and combinations thereof. There
6 are other fluorinated enchants in a substantially gas phase during the etching of the structure.
7 An inert gas is often used in combination with the fluorinated etchant. Argon, nitrogen, and
8 helium are examples of such an inert gas. The preferred gasses, however, are CF₄, CH₂F₂,
9 CHF₃ and Ar. Alternatively CH₃F may be used in place of CH₂F₂. In particular, the
10 preferred enchant is a fluorine deficient gas which is defined as a gas where there are not
11 enough fluorine atoms to saturate the bonding for the carbon atoms.

12 A conductive material is formed upon contact 34 between spacers 28 within second
13 selected pattern 17 as shown in Figure 4. The conductive material will form a contact plug
14 to contact 34. It may be desirable to clad the contact plug with a refractory metal or a
15 refractory metal silicide. As such, second selected pattern 17 would have proximate thereto
16 the refractory metal or silicide thereof prior to formation of the contact plug in contact with
17 contact 34.

18 The present invention has application to a wide variety of structures. The top layer
19 of the gate stack, composed of undoped silicon dioxide, can be used to create and protect
20 various types of structures during the doped silicon dioxide etching process for structures
21 other than gate stacks.

22 The present invention allows the gate stack height to be reduced. One advantage of
23 reducing the gate stack height is to reduce the process time which results in greater
24 throughput. The reduced gate height results in a lower etch time and a reduced contact hole
25 aspect ratio, the latter being defined as the ratio of height to width of the contact hole. By
26 reducing the aspect ratio, or by reducing the height of the gate stack, there will be a decrease

1 in the etch time. Another advantage of a lower gate stack height is that it reduces the overall
2 topography which in turn results in it being easier to planarize and to use photolithographic
3 processes. As such, the present invention increases yield.

4 The present invention may be embodied in other specific forms without departing
5 from its spirit or essential characteristics. The described embodiments are to be considered
6 in all respects only as illustrative and not restrictive. The scope of the invention is, therefore,
7 indicated by the appended claims rather than by the foregoing description. All changes
8 which come within the meaning and range of equivalency of the claims are to be embraced
9 within their scope.

10 What is claimed and desired to be secured by United States Patent is:

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1 1. A process for forming a contact opening to a semiconductor material, said
2 process comprising:

3 forming a substantially undoped silicon dioxide layer over a layer of
4 semiconductor material;

5 forming a doped silicon dioxide layer over said undoped silicon dioxide layer;
6 and

7 selectively removing a portion of said doped silicon dioxide layer at a
8 material removal rate that is at least 10 times higher for doped silicon dioxide than
9 for undoped silicon dioxide or for said layer of semiconductor material to form an
10 opening extending to a contact surface on said layer of semiconductor material.

11
12 2. A process as recited in Claim 1, wherein selectively removing said doped
13 silicon dioxide layer comprises:

14 forming a layer of photoresist over said doped silicon dioxide layer;

15 patterning said layer of photoresist; and

16 etching said doped silicon dioxide layer through the pattern of said layer of
17 photoresist.

18
19 3. A process as recited in Claim 1, wherein the semiconductor material is
20 monocrystalline silicon.

21
22 4. A process as recited in Claim 1, wherein selectively removing said doped
23 silicon dioxide layer comprises a plasma etching process for etching said doped silicon
24 dioxide layer in a plasma etcher.

1 5. A process as recited in Claim 4, wherein said plasma etching process has a
2 plasma density in a range from about 10^9 /cm³ to about 10^{13} /cm³

3
4 6. A process as recited in Claim 4, wherein said plasma etching process is
5 conducted in a pressure range from about 1 millitorr to about 400 millitorr.

6
7 7. A process as recited in Claim 4, wherein during said plasma etching process
8 said reactor cathode has a temperature range from about 10°C to about 80°C.

9
10 8. A process as recited in Claim 4, wherein the temperature range of the
11 semiconductor material during said plasma etching process is from about 40°C to about
12 130°C.

13
14 9. A process as defined in Claim 1, wherein selectively removing said doped
15 silicon dioxide layer comprises etching of said doped silicon dioxide with an etchant selected
16 from the group consisting of C₂F₆, CF₄, C₃F₈, C₄F₁₀, C₂F₈, CH₂F₂, CHF₃, C₂HF₅, and CH₃F.

17
18 10. A process as defined in Claim 9, wherein selectively removing said doped
19 silicon dioxide layer comprises etching of said doped silicon dioxide with an etchant selected
20 from the group consisting of CH₂F₂ and CH₃F.

21
22 11. A process as recited in Claim 1, wherein selectively removing said doped
23 silicon dioxide layer comprises etching of said doped silicon dioxide with a fluorinated
24 chemical etchant.

1 12. A process as recited in Claim 1, wherein said doped silicon dioxide layer is
2 selected from the group consisting of BPSG, PSG, and BSG.

3
4 13. A process for forming contact to a semiconductor material, said process
5 comprising:

6 forming a substantially undoped silicon dioxide layer over a layer of
7 monocrystalline silicon;

8 forming a doped silicon dioxide layer over said undoped silicon dioxide layer,
9 said doped silicon dioxide layer being selected from the group consisting of BPSG,
10 PSG, and BSG;

11 forming a layer of photoresist over said doped silicon dioxide layer;

12 patterning said layer of photoresist;

13 etching said doped silicon dioxide layer through the pattern of said layer of
14 photoresist in a plasma etching process in a plasma etcher, said plasma etching
15 process being conducted:

16 at a pressure range from about 1 millitorr to about 400 millitorr;

17 a temperature range of the cathode that is from about 10°C to about
18 80°C;

19 in a plasma density in a range from about $10^9 / \text{cm}^3$ to about $10^{13} / \text{cm}^3$
20 with a fluorinated chemical etchant; and

21 whereby a contact is exposed on said layer of monocrystalline silicon.

22
23 14. A process as recited in Claim 13, wherein the temperature range of the
24 semiconductor material during said plasma etching process is from about 40°C to about
25 130°C.
26

1 15. A process as recited in Claim 13, wherein said fluorinated chemical etchant
2 comprises an etchant selected from the group consisting of C₂F₆, CF₄, C₃F₈, C₄F₁₀, C₂F₈,
3 CH₂F₂, CHF₃, C₂HF₅, and CH₃F.

4
5 16. A process as defined in Claim 15, wherein selectively removing said doped
6 silicon dioxide layer comprises etching of said doped silicon dioxide with an etchant selected
7 from the group of CH₂F₂ and CH₃F.

8
9 17. A process as recited in Claim 13, wherein said plasma etching process is
10 conducted at a material removal rate that is at least 10 times higher for doped silicon dioxide
11 than for undoped silicon dioxide or for said semiconductor material.

- 1 18. A process for forming a contact to a semiconductor substrate comprising:
2 providing a gate oxide layer over the semiconductor substrate;
3 providing a pair of gate stacks in spaced relation to one another on the
4 semiconductor substrate, each of said gate stacks having at least one conductive layer
5 formed therein and a substantially undoped silicon dioxide layer extending over said
6 conductive layer;
7 forming a spacer adjacent to each of said gate stacks;
8 forming a doped silicon dioxide layer over said pair of gate stacks and over
9 said exposed surface on said semiconductor substrate;
10 selectively removing a portion of said doped silicon dioxide layer between
11 said pair of gate stacks to expose said surface on said semiconductor substrate, while
12 removing substantially less of said undoped silicon dioxide layer over said pair of
13 gate stacks, wherein said etching removes doped silicon dioxide at a material
14 removal rate that is at least 10 times higher than for each of undoped silicon dioxide,
15 the spacer material the spacer material, and the semiconductor substrate.
16
17 19. A process as recited in Claim 18, further comprising:
18 forming polysilicon layer over said gate oxide layer;
19 forming a refractory metal silicide layer over said polysilicon layer; and
20 forming a substantially undoped silicon dioxide layer over said refractory
21 metal silicide layer.
22
23 20. A process as recited in Claim 19, further comprising selectively removing
24 portions of said substantially undoped silicon dioxide layer, said refractory metal silicide
25 layer, said polysilicon layer, and said gate oxide layer.
26

- 1 21. A process as recited in Claim 18, wherein said gate stack comprises:
2 said substantially undoped silicon dioxide layer as the top layer thereof;
3 a refractory metal silicide layer;
4 a polysilicon layer; and
5 a gate oxide layer as the bottom layer thereof.
- 6
- 7 22. A process as recited in Claim 18, wherein the spacer material is substantially
8 composed of silicon nitride.
- 9
- 10 23. A process as recited in Claim 18, wherein the spacer material is composed of
11 substantially undoped silicon dioxide.
- 12
- 13 24. A process as recited in Claim 18, wherein the semiconductor material is
14 monocrystalline silicon.
- 15
- 16 25. A process as recited in Claim 18, wherein said plasma etcher is selected from
17 the group consisting of an RF RIE etcher, a MERIE etcher, and a high density plasma etcher.
- 18
- 19 26. A process as recited in Claim 18, further comprising the step of forming a
20 contact plug composed of a conductive material and situated between said pair of gate stacks
21 and over said surface on said semiconductor substrate.
- 22
- 23 27. A process as recited in Claim 21, wherein said refractory metal silicide layer
24 is tungsten silicide.
- 25
- 26

1 28. A process as recited in Claim 18, wherein said doped silicon dioxide layer is
2 selected from the group consisting of BPSG, PSG, and BSG.

3
4 29. A process as recited in Claim 18, wherein selectively removing said doped
5 silicon dioxide layer comprises:

6 forming a layer of photoresist over said doped silicon dioxide layer;
7 patterning said layer of photoresist; and
8 etching said doped silicon dioxide layer through the pattern of said layer of
9 photoresist in a plasma etching process in a plasma etcher, said plasma etching
10 process being conducted:

11 at a pressure range from about 1 millitorr to about 400 millitorr;
12 a temperature range of reactor cathode that is from about 10°C to
13 about 80°C;
14 a temperature range of the semiconductor material is from about
15 40°C to about 130°C;

16 in a plasma density in a range from about $10^9 /cm^3$ to about $10^{13} /cm^3$
17 and

18 with a fluorinated chemical etchant.

19
20 30. A process as recited in Claim 29, wherein said fluorinated chemical etchants
21 is selected from the group consisting of C_2F_6 , CF_4 , C_3F_8 , C_4F_{10} , C_2F_8 , CH_2F_2 , CHF_3 , C_2HF_5 ,
22 and CH_3F .

- 1 31. A process for forming a contact to a semiconductor material comprising:
- 2 depositing a gate oxide layer over a layer of silicon of a semiconductor
- 3 substrate;
- 4 depositing a polysilicon layer over said gate oxide layer;
- 5 depositing a refractory metal silicide layer over said polysilicon layer;
- 6 depositing a substantially undoped silicon dioxide layer over said refractory
- 7 metal silicide layer;
- 8 selectively removing portions of said substantially undoped silicon dioxide
- 9 layer, said refractory metal silicide layer, said polysilicon layer, and said gate oxide
- 10 layer so as to form a pair of gate stacks separated by an exposed portion of said
- 11 silicon layer, each said gate stack having a lateral side substantially perpendicular
- 12 to said gate oxide layer and being composed of:
- 13 said substantially undoped silicon dioxide layer as the top layer
- 14 thereof;
- 15 said refractory metal silicide layer;
- 16 said polysilicon layer; and
- 17 said gate oxide layer as the bottom layer thereof;
- 18 forming a spacer on the lateral side of each said gate stack from a layer of
- 19 spacer material;
- 20 depositing a doped silicon dioxide layer over said pair of gate stacks and over
- 21 said exposed portion of said silicon layer, said doped silicon dioxide layer being selected from the group consisting of BPSG, PSG, and BSG; and
- 22 etching said doped silicon dioxide layer with a plasma etching system having
- 23 a plasma density in a range from about 10^9 /cm³ to about 10^{13} /cm³ in an etcher
- 24 selected from a group consisting of RF RIE, MERIE plasma etching system, and high
- 25 density plasma etching system, said plasma etching system having a pressure range
- 26

1 from about 1 millitorr to about 400 millitorr, said doped silicon dioxide layer being
2 etched between said pair of gate stacks so as to expose said exposed portion of said
3 silicon layer, said etching having a material removal rate that is at least 10 times
4 higher for doped silicon dioxide than for undoped silicon dioxide, said spacer
5 material, or silicon, said etching of said doped silicon dioxide being conducted with
6 a fluorinated chemical etchant.

7

8 32. A process as recited in Claim 31, wherein the spacer material is substantially
9 composed of one of silicon nitride and substantially undoped silicon dioxide.

10

11 33. A process as recited in Claim 31, further comprising forming a contact plug
12 composed of a conductive material and situated between said pair of gate stacks and over the
13 exposed portion of said silicon layer.

14

15 34. A process as recited in Claim 34, wherein said fluorinated chemical etchant
16 is selected from the group consisting of C_2F_6 , CF_4 , C_3F_8 , C_4F_{10} , C_2F_8 , CH_2F_2 , CHF_3 , C_2HF_5 ,
17 and CH_3F .

18

19 35. A process as recited in Claim 31, wherein during etching of said doped silicon
20 dioxide layer with said plasma etching system, the temperature range of said reactor cathode
21 is from about 10°C to about 80°C.

22

23 36. A process as recited in Claim 31, wherein the temperature range of the
24 semiconductor material during said plasma etching process is from about 40°C to about
25 130°C.

- 1 37. A process for forming a gate structure comprising:
- 2 providing a multilayer structure comprising a layer of silicon dioxide over a
- 3 layer of silicon;
- 4 depositing a layer of substantially undoped silicon dioxide over said
- 5 multilayer structure using a precursor having a gaseous silane, hydrogen, and oxygen
- 6 flow;
- 7 forming a first layer of photoresist over said layer of undoped silicon dioxide;
- 8 patterning said first photoresist layer to form a first pattern;
- 9 etching said layer of undoped silicon dioxide and said multilayer structure
- 10 through said first pattern to expose a contact surface on at least a portion of said layer
- 11 of silicon;
- 12 depositing a layer of a nonconductive material over said layer of undoped
- 13 silicon dioxide and said contact surface on said layer of silicon;
- 14 etching said layer of said nonconductive material to thereby create a spacer
- 15 over a lateral side of said layer of undoped silicon dioxide and over a lateral side of
- 16 said multilayer structure, said spacer being generally perpendicular to said layer of
- 17 silicon;
- 18 removing said first layer of photoresist;
- 19 depositing a doped silicon dioxide layer over said multilayer structure;
- 20 forming a said second layer of photoresist over said layer of doped silicon
- 21 dioxide;
- 22 patterning said second layer of photoresist to form a second pattern;
- 23 etching said layer of doped silicon dioxide and said multilayer structure with
- 24 a carbon fluorine etch through said second pattern to expose said contact surface on
- 25 said layer of silicon, said etching having a material removal rate that is at least
- 26

10 times greater for doped silicon dioxide than for substantially undoped silicon
dioxide, photoresist, or nonconductive material;

removing said second layer of photoresist; and

forming a contact plug composed of a conductive material in contact with
said contact surface on said layer of silicon.

38. A process as recited in Claim 37, wherein said nonconductive material is one
of silicon nitride and substantially undoped silicon dioxide.

39. A process as recited in Claim 37, wherein said carbon fluorine etch is an
anisotropic plasma etch using fluorinated chemical etchants selected from a group consisting
of C₂F₆, CF₄, C₃F₈, C₄F₁₀, C₂F₈, CH₂F₂, CHF₃, C₂HF₅, and CH₃F.

40. A process as recited in Claim 37, wherein said multilayer structure further
comprises layers of gate oxide, polysilicon, and refractory metal silicide.

41. A process as recited in Claim 37, wherein said doped silicon dioxide layer is
selected from a group consisting of BPSG, PSG, and BSG.

42. A process as recited in Claim 37, wherein etching said layer of doped silicon
dioxide and said multilayer structure with a carbon fluorine etch utilizes a plasma etching
system selected from a group consisting of RF RIE, MERIE system, and a high density
plasma etch system.

1 43. A process as recited in Claim 37, wherein etching said layer of doped silicon
2 dioxide and said multilayer structure with a carbon fluorine etch is a plasma etching process
3 being conducted:

4 at a pressure range from about 1 millitorr to about 400 millitorr;
5 a temperature range of reactor cathode that is from about 10°C to about 80°C;
6 a temperature range of the semiconductor material is from about 40°C to
7 about 130°C;
8 in a plasma density in a range from about 10⁹/cm³ to about 10¹³/cm³; and
9 with a fluorinated chemical etchant.

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- 1 44. A process for forming a gate structure comprising:
- 2 providing a multilayer structure situated over a layer of silicon and
- 3 comprising layers of gate oxide, polysilicon, and refractory metal silicide;
- 4 depositing a layer of substantially undoped silicon dioxide over said
- 5 multilayer structure using a precursor having a gaseous silane, hydrogen, and oxygen
- 6 flow;
- 7 forming a first layer of photoresist over said layer of undoped silicon dioxide;
- 8 patterning said first photoresist layer to form a first pattern;
- 9 etching said layer of undoped silicon dioxide and said multilayer structure
- 10 through said first pattern to expose a contact surface on at least a portion of said layer
- 11 of silicon;
- 12 removing said first layer of photoresist;
- 13 depositing a layer of a nonconductive material over said layer of undoped
- 14 silicon dioxide and said contact surface on said layer of silicon;
- 15 etching said layer of said nonconductive material to thereby create a spacer
- 16 over a lateral side of said layer of undoped silicon dioxide and over a lateral side of
- 17 said multilayer structure, said spacer being generally perpendicular to said layer of
- 18 silicon;
- 19 depositing a doped silicon dioxide layer over said multilayer structure and
- 20 over said contact surface on said layer of silicon, wherein said doped silicon dioxide
- 21 layer is selected from a group consisting of BPSG, PSG, and BSG;
- 22 forming a said second layer of photoresist over said layer of doped silicon
- 23 dioxide;
- 24 patterning said second layer of photoresist to form a second pattern;
- 25 etching said layer of doped silicon dioxide and said multilayer structure with
- 26 a carbon fluorine etch through said second pattern to expose said contact surface on

1 said layer of silicon, said etching having a material removal rate that is at least
2 10 times greater for doped silicon dioxide than for substantially undoped silicon
3 dioxide, photoresist, or nonconductive material, wherein said carbon fluorine etch is
4 an anisotropic plasma etch using a fluorinated chemical etchant, wherein said etching
5 of said doped silicon dioxide utilizes a plasma etching system having a plasma
6 density in a range from about 10^9 /cm³ to about 10^{13} /cm³ at a pressure in a range
7 from about 1 millitorr to about 400 millitorr, the temperature range of said reactor
8 cathode during said plasma etch being about 10°C to about 80°C, and the
9 temperature range of the semiconductor material during said plasma etch being in the
10 range of about 40°C to about 130°C;

11 removing said second layer of photoresist; and
12 forming a contact plug composed of a conductive material in contact with
13 said contact surface on said layer of silicon.

14
15 45. A process as recited in Claim 44, wherein said fluorinated chemical etchant
16 is selected from a group consisting of C₂F₆, CF₄, C₃F₈, C₄F₁₀, C₂F₈, CH₂F₂, CHF₃, C₂HF₅, and
17 CH₃F.

18
19 46. A process as recited in Claim 44, wherein said nonconductive material is one
20 of silicon nitride and substantially undoped silicon dioxide.

- 1 47. A gate structure comprising:
- 2 a pair of gate stacks situated over a base silicon layer, each said gate stack
- 3 comprising:
- 4 a gate oxide layer on said base silicon layer;
- 5 a polysilicon gate layer on said gate oxide layer;
- 6 a layer of refractory metal silicide on said polysilicon gate layer;
- 7 a substantially undoped silicon dioxide cap on said layer of refractory
- 8 metal silicide;
- 9 a spacer in contact with a lateral side of each said gate stack and with said
- 10 base silicon layer, said spacer being composed of a nonconductive material, each said
- 11 lateral side of each said gate stack being substantially perpendicular to said base
- 12 silicon layer;
- 13 a contact plug in contact with said base silicon layer composed of a
- 14 conductive material, and being situated between said pair of gate stacks; and
- 15 a layer of doped silicon dioxide over said spacer, over said substantially
- 16 undoped silicon dioxide cap, and in contact with said contact plug.
- 17
- 18 48. A gate structure as recited in Claim 47, wherein said nonconductive material
- 19 is substantially composed of silicon nitride.
- 20
- 21 49. The gate structure as recited in Claim 47, wherein said nonconductive
- 22 material is substantially composed of substantially undoped silicon dioxide, and each said
- 23 spacer is integral with a respective one of said substantially undoped silicon dioxide cap.
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1 50. A method of forming a self-aligned contact, said method comprising:
2 providing a pair of gate stacks in spaced apart relation to one another on said
3 semiconductor substrate, each of said gate stacks being covered by a substantially
4 undoped silicon dioxide layer;
5 forming a spacer adjacent to each of said gate stacks;
6 forming a doped silicon dioxide layer over said pair of gate stacks and over
7 said semiconductor substrate;
8 forming a layer of photoresist over said silicon dioxide layer;
9 patterning said layer of photoresist; and
10 selectively removing a portion of said doped silicon dioxide layer between
11 said pair of gate stacks to expose a contact surface on said semiconductor substrate
12 through said pattern of said layer of photoresist, while removing substantially less of
13 said undoped silicon dioxide layer over said pair of gate stacks than doped silicon
14 photoresist, , said undoped silicon layer being capable of resisting said selective
15 removal process thereby causing said selective removal process to be self-aligning
16 between said pair of gate stacks.

17
18 51. A method as recited in Claim 50, wherein said selective removal of said
19 doped silicon dioxide layer comprises etching said doped silicon dioxide layer in a plasma
20 etching process being conducted:

21 at a pressure range from about 1 millitorr to about 400 millitorr;
22 a temperature range of the cathode that is from about 10°C to about 80°C;
23 in a plasma density in a range from about 10^9 /cm³ to about 10^{13} /cm³ and
24 with a fluorinated chemical etchants.

1 52. A method as recited in Claim 51, wherein the temperature range of the
2 semiconductor material during said plasma etching process is from about 40°C to about
3 130°C.

4

5 53. A method as recited in Claim 51, wherein said fluorinated chemical etchant
6 comprises an etchant selected from the group consisting of C₂F₆, CF₄, C₃F₈, C₄F₁₀, C₂F₈,
7 CH₂F₂, CHF₃, C₂HF₅, and CH₃F.

8

9 54. A method as recited in Claim 50, wherein said plasma etching process is
10 conducted at a material removal rate that is at least 10 times higher for doped silicon dioxide
11 than for undoped silicon dioxide or for semiconductor material.

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1

ABSTRACT OF THE INVENTION

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The present invention relates to a process for selectively plasma etching a structure upon a semiconductor substrate to form designated topographical structure thereon utilizing an undoped silicon dioxide layer as an etch stop. In one embodiment, a substantially undoped silicon dioxide layer is formed upon a layer of semiconductor material. A doped silicon dioxide layer is then formed upon said undoped silicon dioxide layer. The doped silicon dioxide layer is etched to create the topographical structure. The etch has a material removal rate that is at least 10 times higher for doped silicon dioxide than for undoped silicon dioxide or the semiconductor material. One application of the inventive process includes selectively plasma etching a multilayer structure to form a self-aligned contact between adjacent gate stacks and a novel gate structure resulting therefrom. In the application, a multilayer structure is first formed comprising layers of silicon, gate oxide, polysilicon, and tungsten silicide. An undoped silicon dioxide layer is formed over the multilayer structure. After patterning and etching, the multilayer structure to form gate stacks therefrom, a layer silicon nitride is deposited and is etched to create spacers on the gate stacks that are generally perpendicular to the silicon layer. Doped silicon dioxide is then deposited over the gate stacks and corresponding spacers. A photoresist layer is utilized to expose selective portions of silicon dioxide layer above the contacts on the silicon layer that are to be exposed by etching down through the doped silicon dioxide layer. The doped silicon dioxide is then selectively etched using an anisotropical plasma etch that utilizes a carbon fluorine etch. The novel gate structure comprising an undoped silicon dioxide cap is capable of resisting a carbon fluorine etch.

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PATENT APPLICATION
Docket: 11675.114

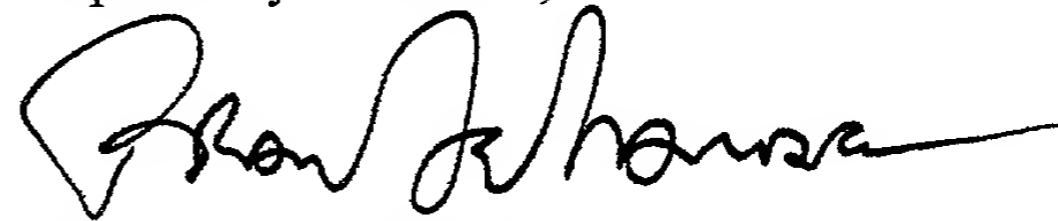
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Date of Deposit: 30th April 1997

I hereby certify that this patent application in the name of Kei-Yu Ko for UNDOPED SILICON DIOXIDE AS ETCH STOP FOR SELECTIVE ETCH OF DOPED SILICON DIOXIDE, together with the Declaration, Power of Attorney, and Petition, Assignment, two (2) sheets of drawings, and Check No. 096901 for \$1,890.00, are being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 C.F.R. § 1.10 on the date indicated above in an envelope addressed to the Commissioner of Patents and Trademarks, Washington, D.C. 20231. Dated this 30th day of April, 1997.

Respectfully submitted,



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BKD:dff

Transmitted: Transmittal; Application (32 pages of specification and claims); Drawings (2 sheets); Declaration, Power of Attorney and Petition; Assignment with coversheet; Check No. 096901 for \$1,890.00 for filing fees and assignment recordal; postcard.

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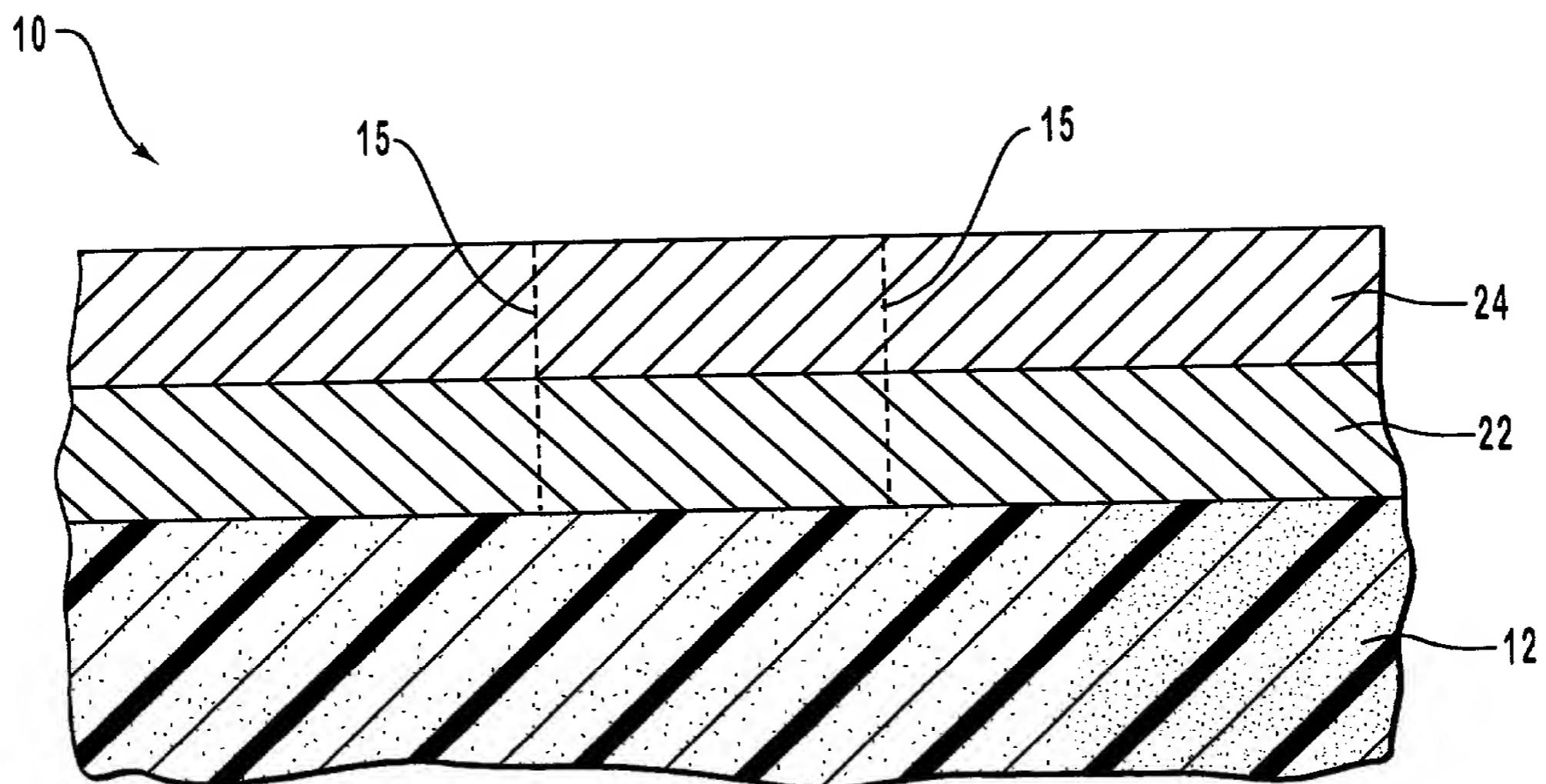


FIG. 1

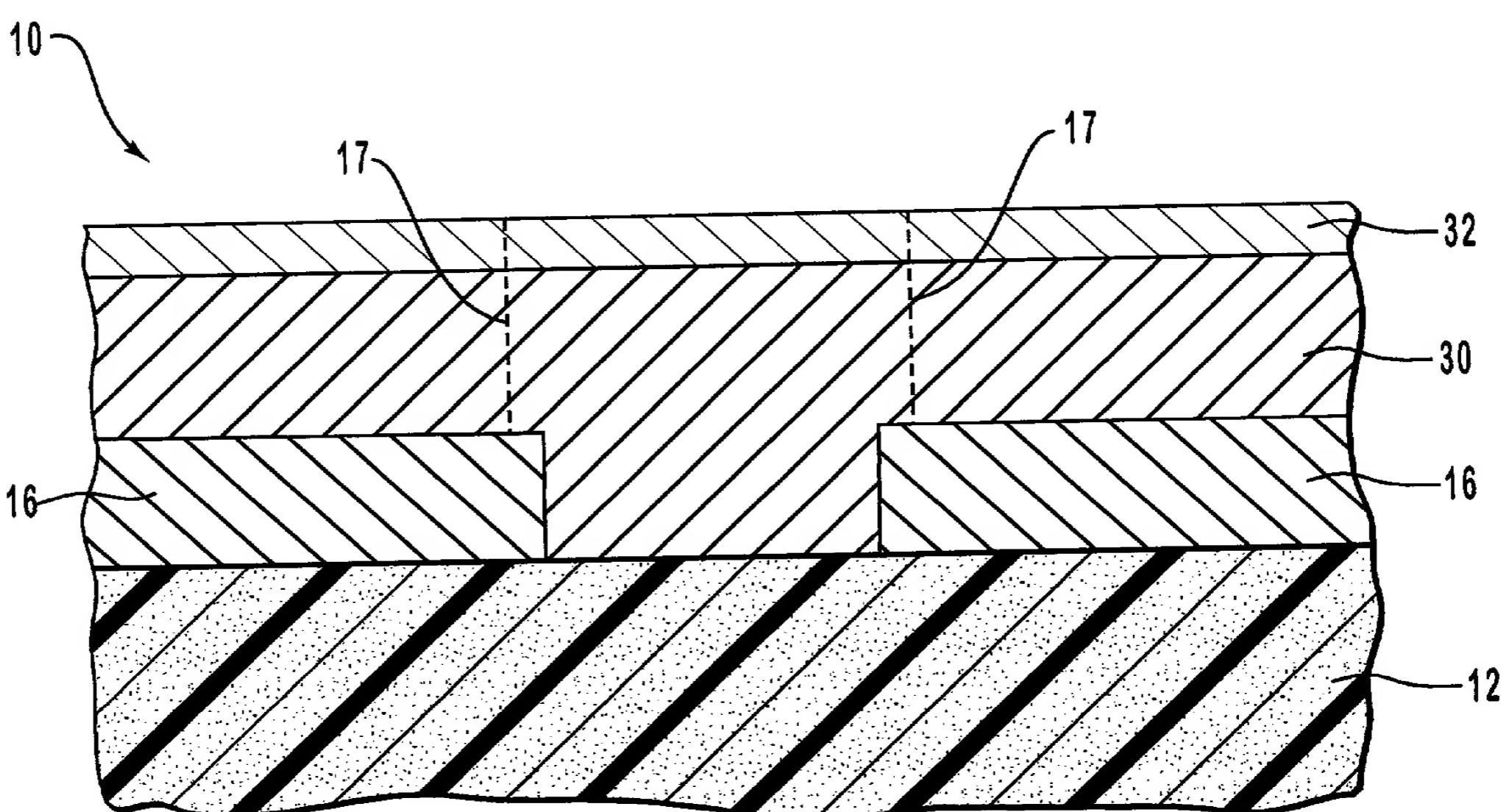


FIG. 2

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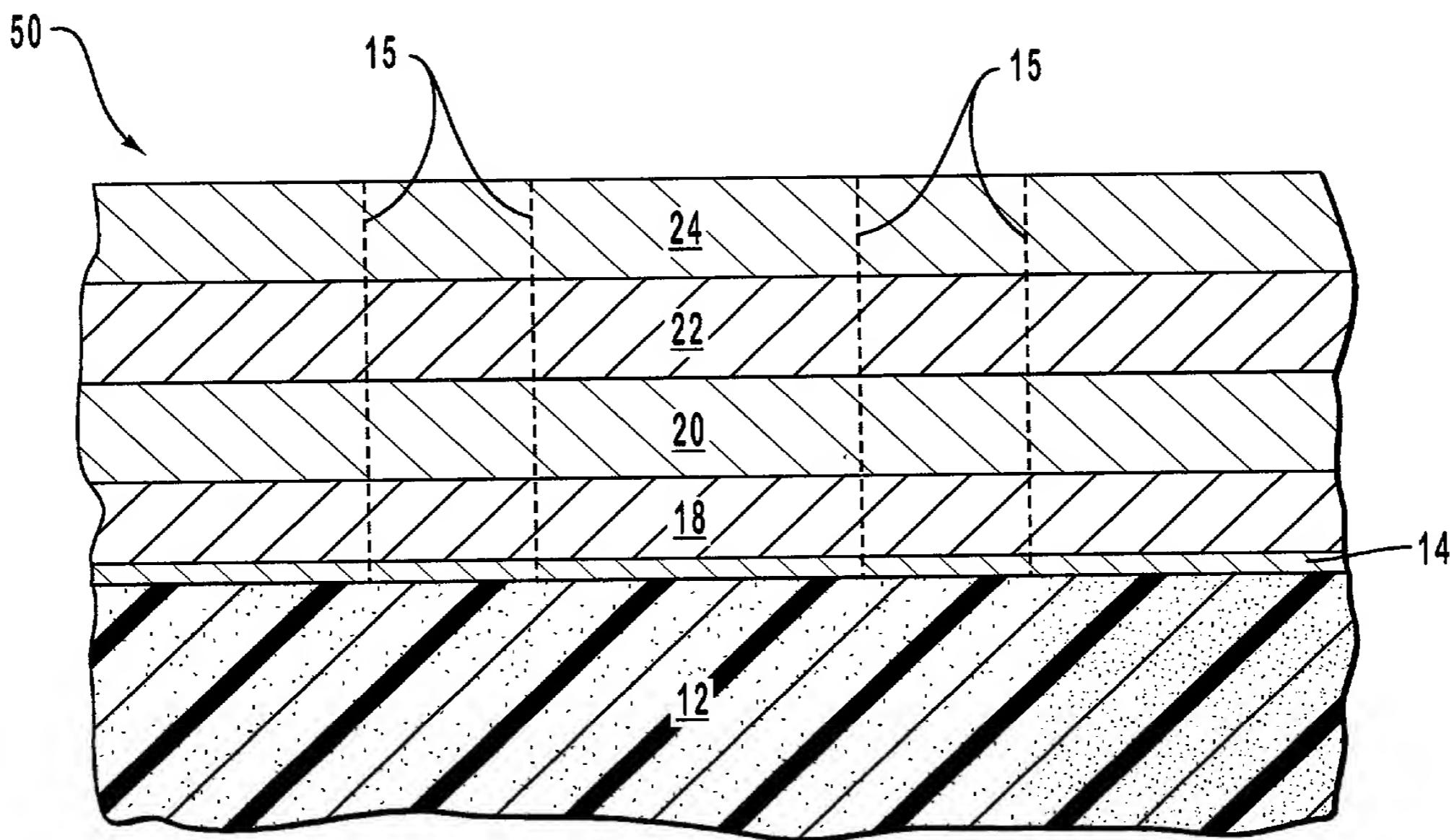


FIG. 3

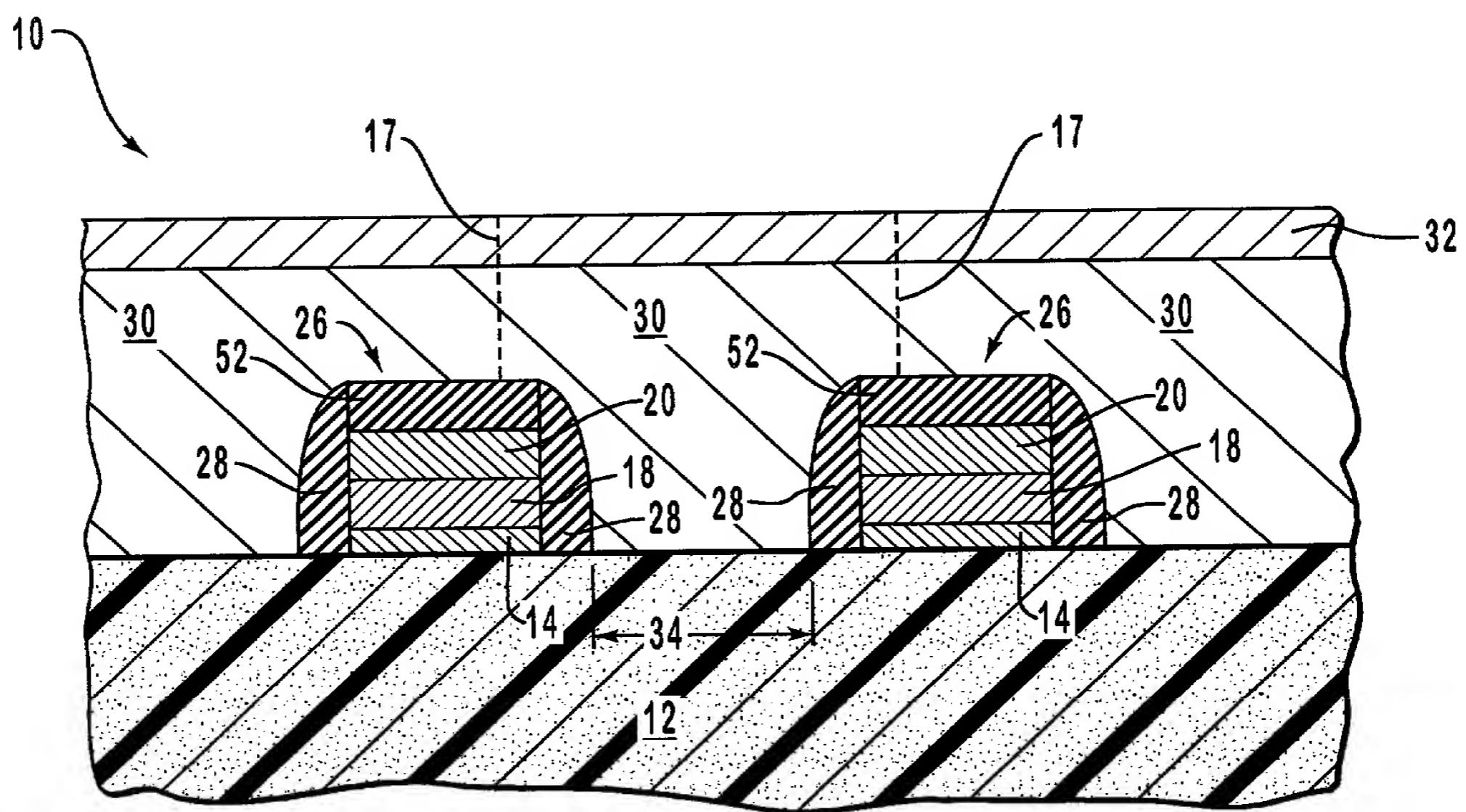


FIG. 4

DECLARATION, POWER OF ATTORNEY, AND PETITION

I, Kei-Yu Ko, declare: that I am a citizen of the United States of America; that my residence and post office address is 4611 E. Rockbury Ct., Meridian, Idaho 83642; that I verily believe I am the original, first, and sole inventor of the subject matter of the invention or discovery entitled UNDOPED SILICON DIOXIDE AS ETCH STOP FOR SELECTIVE ETCH OF DOPED SILICON DIOXIDE, for which a patent is sought and which is described and claimed in the specification attached hereto; that I have reviewed and understand the contents of the above-identified specification, including the claims; and that I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Section 1.56(a) of Title 37 of the Code of Federal Regulations.

I declare further that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful, false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful, false statements may jeopardize the validity of the application or any patent issuing thereon.

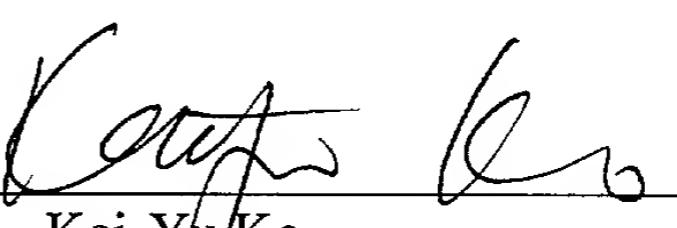
I hereby appoint as my attorneys and/or patent agents: H. ROSS WORKMAN, Registration No. 25,230; RICK D. NYDEGGER, Registration No. 28,651; DAVID O. SEELEY, Registration No. 30,148; JONATHAN W. RICHARDS, Registration No. 29,843; JOHN C. STRINGHAM, Registration No. P-40,831; MICHAEL F. KRIEGER, Registration No. 35,232; BRADLEY K. DeSANDRO, Registration No. 34,521; JOHN M. GUYNN, Registration No. 36,153; GREGORY

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BRADLEY K. DeSANDRO
WORKMAN, NYDEGGER & SEELEY
1000 Eagle Gate Tower
60 East South Temple
Salt Lake City, Utah 84111

Wherefore, I pray that Letters Patent be granted to me for the invention or discovery described and claimed in the foregoing specification and claims, declaration, power of attorney, and this petition.

Signed at Boise, Idaho, this 28 day of
April, 1997

Inventor: 
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